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Aerosol forcing efficiency in the UV region from cloudless irradiance measurements at an urban-marine environment

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Methodology

The aerosol radiative forcing efficiency (RFE) is defined as the rate at which the irradiance at a certain wavelength range is "forced" (changing) per unit of aerosol optical depth (D_{AOD}).

The irradiance change DI was calculated as:

$$DI_i = I_i - MI_i$$

where I_i are the integrals of 325-340nm or 355-360 nm range and MI_i is the Radiative Transfer Model calculation of the irradiance for the same solar zenith angle, wavelength ranges and for an aerosol free (AOD_{340nm}=0) atmosphere.

AOD was calculated from direct sun spectral measurements performed within ±20 minutes from each of the UV irradiance measurement. For calculating RFE the AOD in the slant path (AODs) was used normalizing the retrieved AOD with the air mass factor for each measurement. In addition, the percent RFE (RFE%) was calculated.

So, if **DI% = (DI)/MI** then RFE% is defined as **RFE%=[100*DI%]**. It provides the percent change of the irradiance at the given wavelength range per unit of AODs.

For analyzing all the above parameters the methodology described in Garcia et al., 2006 was used. RFE and RFE% were calculated using monthly and seasonal (3 month) measurement data sets. An example of the RFE% calculation for summer of 1998 is shown in figure 1. In this figure DI% versus AODs is shown. The calculated slope is the RFE%. The calculated RFE% using the Garcia et al., 2006 bin analysis and the RFE% calculated from the actual points are -11.44% and -11.40% respectively. The correlation coefficient of the bin analysis is -0.996. The fact that clear sky UV irradiances for wintertime (December-February) are limited, in addition to the bin analysis criterion of using solar zenith angles smaller than 60 degrees, leads to the exclusion of these periods from the analysis.

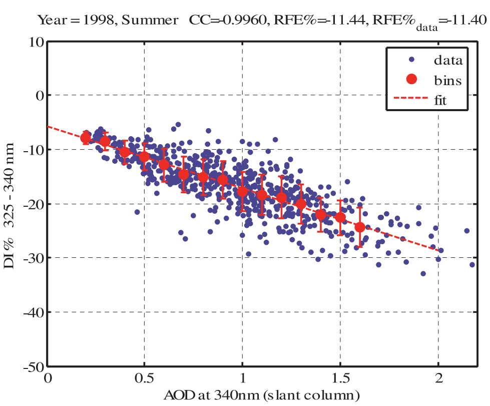

Figure 1. Irradiance percentage change (DI%) calculated for summer 1998 versus aerosol optical depth slant column.

Instruments, data and site description

Site: The measuring station is located near the center of the city of Thessaloniki on the roof of the Physics Department of the Aristotle University of Thessaloniki (40° 38΄ N, 22° 57΄ E, 80m asl). The UV monitoring station of Thessaloniki has one of the longest records of spectral UV irradiance measurements and for this study cloudless spectral measurements from 1998 - 2007 were used.

Instrument: Spectral UV irradiance used in this study was measured with a Brewer MKIII double spectroradiometer at Thessaloniki, Greece (Garane et al., 2006).

UV irradiance: The spectral ranges that were chosen were parts of the UVA wavelength range (325-340 nm and 355-360 nm integrals). The reason for this choice was that the chosen wavelength ranges are only affected by aerosol changes and the ozone effects can be considered negligible.

Aerosol optical depth: Measurements of the aerosol optical depth have been conducted in Thessaloniki, since 1998 also with the Brewer spectroradiometer. More details about the calibration and methodology of the AOD retrieval can be found at Kazadzis et al., 2007. For this study the AOD at 340 nm was used. For the selection of the cloud free days we used the methodology described in Vasaras et al. 2001, which is based on the variability of the measurements from a collocated broadband detector.

Radiative transfer Model: The cloud-free UV irradiance values were calculated from the Uvspec model (Mayer, B., and A. Kylling, 2005). The radiative transfer equation was solved with the discrete ordinates algorithm, using six streams and pseudospherical correction. The Air Force Geophysical Laboratory (AFGL) U.S. standard atmosphere profiles were used for ozone, temperature and air pressure. The type of landscape suggests a relatively small surface albedo, thus the spectrally constant values of 0.03 was used for the while UV region.

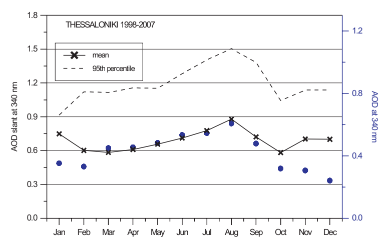

Figure 2: Annual monthly mean AOD at 340 (circles - right axis) and AOD slant column (crosses - left axis) measured for the period 1998-2007.

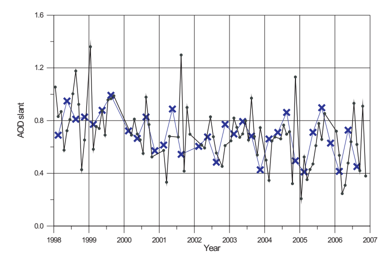

Figure 3: Monthly mean (circles) and 3-month monthly mean (crosses) AOD slant column at 340 measured for the period 1998-2007.

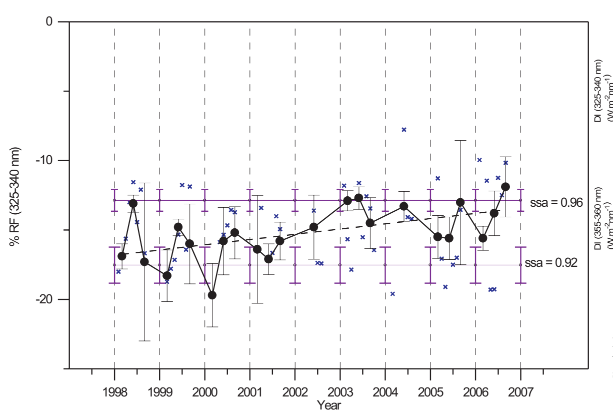

Figure 4. %RFE calculated from 1996-2007. The percentage on the Y axis represent the irradiance reduction for AOD slant column equal to 1. The single scattering albedo values (lines) were calculated with the use of a Radiative transfer model. Circles represent 3 month analysis and crosses monthly analysis of the methodology that was described.

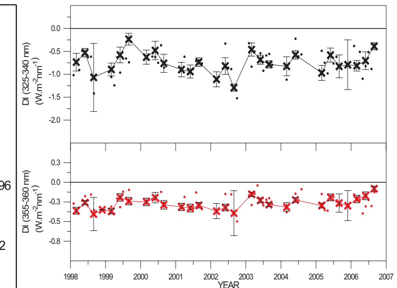

Figure 5. Irradiance change (DI) calculated for two UVA wavelength bands. Crosses represent 3 month means and small circles monthly means

Conclusions - Aerosol effects on UV irradiance

- Aerosols found over Thessaloniki, Greece result from different sources, comprising of a marine component, a mineral dust component (outbreaks of Saharan dust and local dust suspension) and an anthropogenic component. High aerosol optical depths may occur during the presence of either absorbing or non-absorbing particles.

- The seasonal variation of the slant column AODs is shown in figure 2 together with the AOD measurements for the period 1998-2007. Mean slant column AOD at 340 nm for Thessaloniki, for the given period are found to be 0.75, while the 95th percentile statistics give values from 0.9 to 1.5. The clear annual variability of the AOD is smaller when calculating the AODs when the wintertime slant path is larger than the one in summertime. However, still maximum values of AODs are observed in the summer months and especially in August (0.9).

The calculated irradiance change for the 325-340 nm integrals were found to be -0.71 ± 0.30 $W.m^{-2}$/(AODslant at 340nm). Mean RFE% is -13.71±1.93 %, while for spring, summer and winter the RFE% are:-15%, -13%, -13.5% respectively. Taking into account the above percentages and the AODs (figure 2) mean and maximum, the mean and maximum seasonal aerosol impact on the UV irradiance levels for the specific site can be estimated.

- Analyzing the seasonal RFE% for the period 1998-2007, a non significant positive trend of RAF% of ~3% per decade was calculated. This observed change in the aerosol radiative forcing efficiency (and/or any variations of this parameter) can be a hint of a change of the aerosol properties in the area. Using radiative model calculations for calculating factors that could cause such changes, we have calculated that the observed RFE% change could be explained by a change of +0.03 in the mean single scattering albedo of the area during the last decade.

References

Ackerman, A.S. et al., 2000. Effects of aerosols on cloud albedo: Evaluation of Twomey's parameterization of cloud susceptibility using measurements of ship tracks. Journal of the Atmospheric Sciences, 57(16): 2684.

Anderson, T.L. et al., 2003. Climate forcing by aerosols - a hazy picture. Science, 300: 1103-1104.

Charlson, R.J. et al., 1992. Climate forcing by anthropogenic aerosols. Science, 255: 423-430.

Garane K., et al., 2006, Monitoring of UV spectral irradiance at Thessaloniki (1990-2005): Data re-evaluation and quality control. Annales Geophysicae, 24(12): 3215.

García, O. E., A. M. Díaz, F. J. Expósito, J. P. Díaz, J. Gröbner, and V. E. Fioletov (2006), Cloudless aerosol forcing efficiency in the UV region from AERONET and WOUDC databases, Geophys. Res. Lett., 33, L23803, doi:10.1029/2006GL026794.

IPCC, 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. In: J.T. Houghton et al. (Editors). Cambridge University Press, Cambridge, UK, pp. pp. 881.

Kazadzis S., et al, Nine years of UV aerosol optical depth measurements at Thessaloniki, Greece, Atmospheric Chemistry and Physics, Vol. 7, pp 2091-2101, 2007

Mayer, B. and Kylling, A., 2005. Technical note: The libRadtransoftware package for radiative transfer calculations - description and examples of use. Atmospheric Chemistry and Physics, 5: 1855-1877.

Ramanathan, V., et al., 2001. Atmosphere: Aerosols, climate, and the hydrological cycle. Science, 294(5549): 2119.

Rosenfeld, D. and Lensky, I.M., 1998. Satellite-Based Insights into Precipitation Formation Processes in Continental and Maritime Convective Clouds. Bulletin of the American Meteorological Society, 79(11): 2457.

Vasaras, A. Et al., 2001. Comparison of two methods for cloud flagging of spectral UV measurements. Atmospheric Research, 57(1): 31.